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EPILATION AND HAIR GREYING IN HAMSTERS FOLLOWING ONE SINGLE APPLICATION OF BETA RAYS*

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ABSTRACT

Syrian golden and white hamsters were exposed to a single application of beta rays from a Krypton^{85} source in doses of 2,000, 4,000 and 10,000 rads. Permanent epilation was observed in Golden hamsters receiving the highest dose, permanent greying of hair was observed in lower doses. In white hamsters, permanent epilation occurred at lower doses than those for golden hamsters. Intense atrophy of the epidermis was observed histologically in animal's skin exposed to highest doses. A relatively higher mortality rate was observed in animals receiving higher doses of radiation. No spreading of the hair-greying effect of beta rays was observed in this experiment.

In 1896, shortly after Roentgen discovered the x-ray, Daniels reported that x-radiation caused loss of hair in humans (1). Greying of rabbit hair after irradiation was first reported in 1925 by Coolidge (2). Since then, epilation, morphologic abnormalities and depigmentation of hair following radiation have been thoroughly described (3–9).

The sensitivity of hair to epilating effects of ionizing radiations varies markedly with the hair cycle. Hair follicles in the anagen stage give a higher response per dose than follicles in the telogen stage at the time of x-irradiation (10). Temporary epilation is probably associated with damage to the epidermal elements of the hair follicles which anchor the hair shaft to the base of the follicle. Permanent epilation, on the other hand, may result from failure of formation of new follicles. Higher doses are required for permanent epilation in comparison to those capable of producing temporary loss of hair because of differences in sensitivity between the dermal and epidermal components of the follicles with respect to the damaging effect of ionizing radiations (11).

The great variability of temporary epilation under different physical conditions of exposure to radiation makes an interspecies comparison of the sensitivity of hair on the basis of temporary epilation extremely difficult. The great variety of methods used by the various investigators precludes such an attempt in most instances. It appears, however, that the fur coat of rabbits and guinea pigs may be considered about 2–3 times more resistant than the hair of man (12). Maximum epilation due to radiation occurs in rats during the active phase of hair growth on the 15th day, while the period of minimal sensitivity corresponds to the resting phase on day 20 or 28 (11).

The depigmentation of hair is a radiation effect which has been also extensively studied. Greying effects of x-radiation are well-known for rabbits, mice and other laboratory animals (4, 5, 13). Hair depigmentation in humans with mycosis fungoides treated with electrons from a Van de Graff generator has been reported (14). Epilation and growth retardation are opposite in severity to the greying effect with respect to active or inactive follicles at the time of treatment. Chase studied the greying response in C57 mice and found that greying increases with an increase in the dosage of x-irradiation and that telogen hairs give the maximum response to greying. High voltages are less efficient in the production of greying than low ones. Exposure of resting hair follicles of mice to x-radiation results in greying effect from a threshold response at 250 r to a 95 to 100 per cent greying responses at 1,000 r. However, doses of x-rays from 1,100 to 1,700 r produce an anomalous response in which the pigment loss may be only 60% (4). Factors which also modify sensitivity to radiation are local oxygenation (6, 8) and the genetic constitution of the animal, although the latter relationship is not clear (4, 6, 7, 8). Direct

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or indirect injury or inactivation of melanocytes is regarded as one of the important factors in hair greying. It seems likely that RNA degraded by irradiation impairs the normal control of pigment formation in melanocytes (15).

Spreading of greying effects to neighboring areas of the skin has been described. After "sub-lethal" doses, white hairs occurred first in the exposed area and then later over the entire body, including the regions which were thought to have been shielded. A transfer of substances from the exposed areas from cell to cell has been postulated (16). Comparable results have not been obtained in other studies; even with doses approaching the level of permanent epilation for the exposed area, no spreading has been discovered (4). Nevertheless, white hairs have been found in the fur of mice injected at birth with irradiated RNA solution but not in the animals which receive nonirradiated RNA (15). On the other hand, epilation in the nonirradiated member of parabiotically united rats has been reported and explained in terms of "transfer of material" from the circulation of one rat to the other (17). These conflicting results make the situation rather indecisive. Results pertinent to this matter will be found in the present report.

It appears that the presence of a high background level of white hairs may be correlated with an increased sensitivity to depigmentation of hair follicles (7–9). We have not been able to find information regarding epilation in relation to this subject. It seemed to us of interest to compare the epilating effect of ionizing radiation in white and golden hamsters.

Most of the information on epilation and hair greying by ionizing radiations have been carried out using x-rays, but among others, beta rays and cosmic rays have been used (18). Snider and Roper, using P^{32} as beta ray source, exposed mice to total body beta radiation of about 2,500 rep and 5,000 rep. After 10 days the mice lost hair on the eye lids, external ear, and back. After 15 days, with the exception of the belly, the hair was thinned out in all parts of the body (19). Moritz, using a variety of beta emitting sources studied the effects of beta irradiation on the lateral and dorsal surfaces of pigs which possess a mosaic pattern of hair growth similar to that of man. Although Moritz does not report the exact time of epilation, he showed that the degree of epilation varies according to the different types of beta particles. Strontium[90] and yttrium[91] produced epilation at 22 and 25 hundreds reb. Beta rays from cesium[137] and cobalt[60] required 50 to 75 hundreds reb while sulfur[35] in doses up to 4,000 hundreds reb did not cause epilation even though the epidermis was destroyed. Since beta particles from strontium[90] and yttrium[91] have the deepest penetration and those from the sulfur[35] the least, these apparent discrepancies were attributed to the depth of penetration of the beta particles from the various sources (20).

Plucking of hair of mice by means of the fingers from several separate areas of the coat is the method of obtaining areas of known stages of hair growth. Plucking of club-hairs from an area stimulates the follicles of that area alone to produce the next hair generation. In mice, six days after plucking the area is in substage anagen 4 as was proved histologically (4). By 8 days after plucking of resting hair the bulbs are nearly at their maximum depth (21).

Relatively few studies of the effect of ionizing radiation on epilation and greying of hair have been done in hamsters. The threshold dose for hamsters to greying effects of radiations has been demonstrated to be similar to that for mice, 200–300 rads (5, 22). The present study was undertaken to study these phenomena in this widely used laboratory animal. Unfortunately, it was not possible for us to find studies in relation of the normal hair cycle of hamsters.

MATERIALS AND METHODS

Syrian golden (23) and white (24) hamsters, 8 weeks of age and weighing approximately 125 grams were used. The animals were kept in plastic cages, 5 animals to a cage with sterilized Sanicell and were fed Purina Chow and water *ad libitum*.

The beta source used was a krypton[85] capsule of 1.5 cm in diameter, supplied by New England Nuclear Corp. At the time of use, the activity was 8.5 mc and of good uniformity of irradiation. The calculated dose was 495 rads per minute in direct contact to the skin. Krypton[85] emits also a 0.5 Mev gamma in about 0.7% of its desintegrations (25). Roughly, the superficial gamma dose is about 1% of the beta dose. At greater depths, the gamma-beta relation dose is increased as a result of a greater disipation of the beta radiation. In any case, even in an infinite medium only approximately 1% of the total energy absorbed would have come from the gamma radiation. The bremsstrahlung for beta rays of this energy absorbed in iron renders 1% of the energy as x-rays. Hence, the bremsstrahlung dose rate could be also

roughly about 1% of the surface of the beta dose. The source was calibrated for radiation dose rate both at the surface of the source and of several depths in tissue equivalent material (cellulose acetate).

Calibration was performed by means of photographic dosimety using the principle described in Hine and Brownell (26). Films were exposed to the beta source for accurately measured periods of time. The film was processed under standard conditions along with appropriate calibration film strips. Quantification was provided by the densitometric comparison of the unknown exposures with the standard exposure. Depth doses were determined by exposure through stacked films, whose beta ray attenuation properities were very near to tissue equivalent.

Dose rate here quoted means specifically the absorbed dose rate in units of rads per minute, averaged over a circle of 3 mm in diameter, in cellulose acetate of approximately unit density at the depth indicated for the source in contact with the surface. Attentuation of activity was studied on levels of 20.2, 40.4, 60.0 and 80.8 mg per square centimeter of cellulose acetate. The attentuation of the source was nearly exponential with an initial half thickness of 28 mg per square centimeter.

The hair of the back of the animals was plucked in an attempt to start a new period of hair growth, in order to synchronize the time of irradiation (27); nevertheless, synchronization was not proven by means of histological studies and only can be assumed.

After 10 days, the new hair was clipped with an electric clipper. Animals were anesthetized with Nembutal (28), and the radioactive source, attached to an inverted photographic tripod (Figs. 1 and 2), was rapidly lowered to come in direct contact with the skin. The time was measured in order to deliver doses ranging from 2,000 to 10,000 rads. After the application the animals were checked once a week by clipping the exposed area, and changes in the skin were recorded on graph paper.

RESULTS AND COMMENTS

Erythematous reactions usually developed within 24 hours after radiation and persisted several days thereafter. Severe radiation dermatitis developed at sites where larger doses were applied and sometimes resulted in ulcerative changes in the epidermis. Great variability of these acute phenomena was observed. Changes regarding epilation and greying of hair after the fifth week of treatment are reported here.

Results in relation to epilation and greying of hair in the exposed areas in the golden and white hamsters can be seen in Figures 3 and 4. It can be observed that doses of 10,000 rads induced complete and permanent epilation in Syrian golden hamsters, doses of 4,000 rads induced epilation up to the 17th week in all males and most of the females. In all animals of this group, growth of grey hair was subsequently observed in the exposed areas. Females receiving

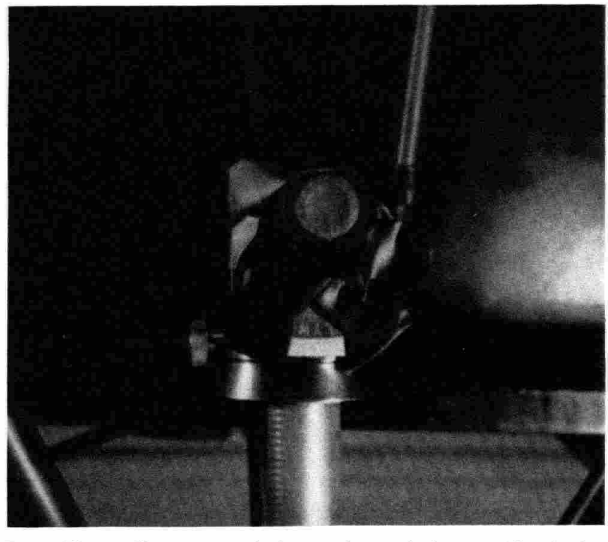

FIG. 1. Krypton^{85} source attached to an inverted photographic tripod.

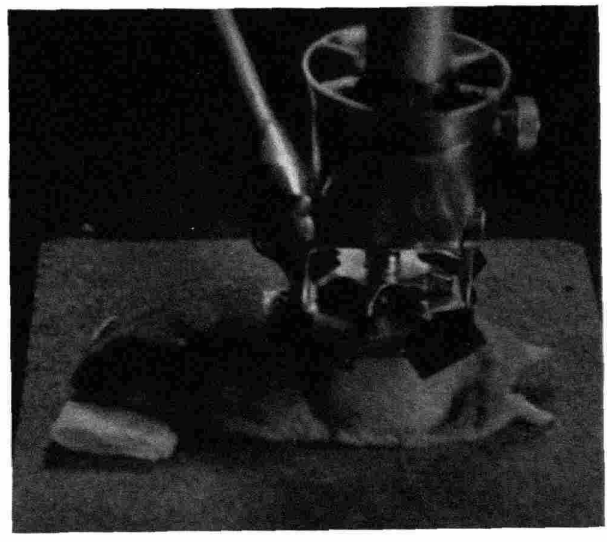

FIG. 2. Krypton^{85} source applied directly to the skin of an anesthetized hamster.

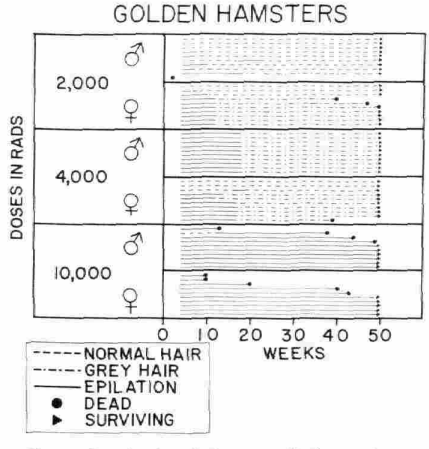

FIG. 3. Results in relation to epilation and greying of hair following a single application of beta rays from a krypton^{85} source in golden hamster.

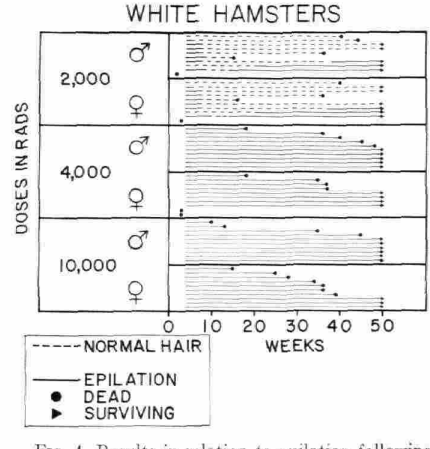

FIG. 4. Results in relation to epilation following a single application of beta from a Krypton^{85} rays to white hamsters.

2,000 rads showed about 12 weeks of epilation followed by growth of grey hair in most of them. Epilation was observed for a short period of time in some of the males. In one male, epilation lasted until the 17th week and growth of grey hair occurred subsequently. In the rest of the males initial and transient periods of epilation were followed by growth of normal hair. Higher mortality was noticed in animals receiving 10,000 rads. Complete epilation occurred in white hamsters receiving 4,000 and 10,000 rads. Recuperation of hair growth in these animals

FIG. 5. White hamster showing epilation in the skin exposed to a single application of beta rays from a Krypton^{85} source, (10,000 rads).

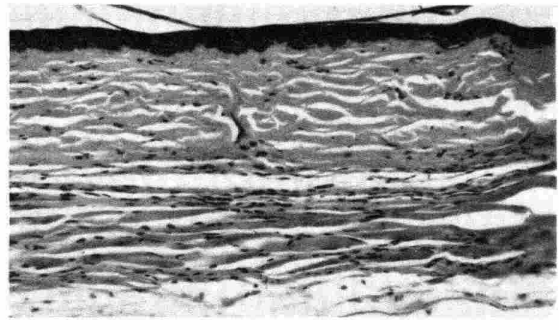

FIG. 6. Skin of a Syrian golden hamster treated with 10,000 rads of a beta source of Krypton^{85}. Note the marked atrophy of epidermis and replacement of skin appendix by fibrous connective tissue.

was not observed. In both groups of animals a high and early death rate was observed. At 2,000 rads level dose results are variable in intensity. In most of the animals, a short period of epilation was followed by growth of normal hair. Few animals showed complete epilation preceded or interrupted for periods of growth of normal hair.

No spreading of the epilation or greying effect was observed in this experiment. Lesions observed in the skin measured the same as the diameter of the radioactive source (Fig. 5).

Surviving animals were killed at the 50th week of observation. All animals were submitted to complete autopsy. Irradiated skin and any other pathological gross findings were studied histologically. Figure 6 shows an example of skin of a Syrian golden hamster treated with 10,000 rads. Marked atrophy of the epidermis can be seen. The underlining tissues are completely replaced by highly compact hyalinized collagen fibers. Sebaceous glands and hair follicles completely disappeared. Changes of this kind were observed also at lower doses but were less intense. The other most common postmortem finding was acute interstital pneumonitis. This syndrome, as cause of death in animals irradiated in the whole body, has been previously reported.

and may account for the early death observed in this experiment (29).

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